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DIGITAL SYSTEM FOR GUDRATURE SYNTHESIZING OF SIGNALS

by

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Digital System for Qudrature Synthesizing of Signals.

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Abstract:

The work discussed the algorithm of an approximate calculation of the function $Z(X, Y)=\sqrt{X^2+Y^2}$ and presents examples of systemic realization of this algorithm.

1. Introduction.

In order to improve detection of signals on the background of interferences recently quadrature reception {1÷3} has been used more frequently in radars. It requires doubling of the TES filtration systems and addition of quadrature system for synthesizing signals according to the rule:

$$Z(X,Y)=\sqrt{X^2+Y^2} \qquad (1)$$

This way one obtains an optimal radio bearing receiver for detection of mobile objects on the bacground of constant echos in which an improvement of the ratio of a signal to noise and elimination of dead* phases takes place. It brings about a significant improvement of detectability (at the level of 10) in comparison to a one channel receiver, (3).

Due to this reason in the majority of contemporary radars a quadrature reception is used, in which the rule for synthesizing signals can be an approximate one, for example:

$$Z(X,Y)=|X| + |Y| \qquad (2)$$

The rule (2) can be easily realized systemically through the digital technics, but its application causes the output signal to be in a certain way modulated by the Doppler frequency. A precise realization of the rule (1) through digital technics is very costly. Because of that

* Literary: blind. Translator.

it became necessary to find an algorithm for an approximate calculation of the value of the function $Z(X,Y)=\sqrt{X^2+Y^2}$ which would ensure a relatively simple systemic realization and not too large error of the approximation.

3. The Algorithm of the Approximation.

Let us consider the following algorithm for calculation of approximate values of the function Z(X,Y):

$$\tilde{Z}(X,Y)=\begin{cases} \gamma(X,Y)\cdot|X|+\alpha(X,Y)\cdot|Y| \\ \text{gdy } |X|\geqslant|Y| \\ \gamma(Y,X)\cdot|Y|+\alpha(Y,X)\cdot|X| \\ \text{gdy } |X|<|Y| \end{cases} \quad (3)$$ gdy - when. Tr.

where:

$\tilde{Z}(X,Y)$ is an approximate value of the function Z(X,Y),

$|X|,|Y|$ are absolute arguments of X and Y,

$\alpha(X,Y)$ and $\gamma(X,Y)$ are certain step functions defined by the dependencies (4) and (5):

$$\alpha(X,Y)=\begin{cases} \alpha_1 \text{ gdy } & |Y|\leqslant\beta_1\cdot|X| \\ \alpha_2 \text{ gdy } & \beta_1\cdot|X|<|Y|\leqslant\beta_2\cdot|X| \\ \alpha_n \text{ gdy } & \beta_{n-1}|X|<|Y|\leqslant|X| \\ 0 \text{ gdy } & |X|<|Y| \end{cases} \quad (4)$$

$$\gamma(X,Y)=\begin{cases} \gamma_1 \text{ gdy } & |Y|\leqslant\beta_1|X| \\ \gamma_2 \text{ gdy } & \beta_1\cdot|X|<|Y|\leqslant\beta_2|X| \\ \gamma_n \text{ gdy } & \beta_{n-1}|X|<|Y|\leqslant|X| \\ 0 \text{ gdy } & |X|<|Y| \end{cases} \quad (5)$$ gdy - when

where $0<\beta_1<\beta_2<\ldots.\beta_{n-1}<1$.

The application of the algorithm (3) reduces calculations of values of the function Z(X,Y) only to performing operations of multiplying and summing, while the accuracy of the approximation dependents on selection of functions $\alpha(X,Y)$ and $\gamma(X,Y)$. In the search for functions $\alpha(X,Y)$ and $\beta(X,Y)$ one should endeavor for α_i,β_i and γ_i to be numbers with a simple binary explication, i.e. for binary explications not to have many ones.

This fact is significant because of the number of elements required for a construction of a system realizing the algorithm of the approximation according to dependency (3). Quite a good accuracy of the approximation is obtained even with simple and easy to realize forms of the functions $\alpha(X,Y)$ and $\beta(X,Y)$. The analysis of errors of the approximation will be conducted below:

3. Analysis of Errors

We can write in a following way a relative error of the approximation of values of a function Z(X,Y) through values of a function Z(X,Y):

$$\varepsilon(X,Y)=\frac{\tilde{Z}(X,Y)-\sqrt{X^2+Y^2}}{\sqrt{X^2+Y^2}} \qquad (6)$$

Because of the analysis of errors, it is more convenient to limit ourselves to the case when $|X|\geq|Y|$, because it does not diminish generality of the discussion, and allows us to simplify writing.

Let $|X|\geq|Y|$, $p=\left|\frac{Y}{X}\right|$ where $0\leq p\leq 1$.

Then dependencies (4), (5) and (6) may be examined as functions of one variable - p:

$$\alpha_0(p)=\alpha(X,p\cdot X) \qquad (4')$$

$$\gamma_0(p)=\gamma(X,p\cdot X) \qquad (5')$$

$$\varepsilon_0(p)=\varepsilon(X,p\cdot X)= =\frac{\gamma_0(p)+\alpha_0(p)\cdot p-\sqrt{1+p^2}}{\sqrt{1+p^2}} \qquad (6')$$

Below we will give two examples of selection of functions $\alpha_0(p)$ and $\gamma_0(p)$ which can be simply realized with the use of digital systems.

Example 1.

The most simple form of the function $\alpha_0(p)$ and $\gamma_0(p)$ is the following:

$$\alpha_o(p) = \begin{cases} \alpha_{11} & \text{gdy } 0 \leqslant p \leqslant 1 \\ 0 & \text{gdy } 1 < p \end{cases}$$

$$\gamma_o(p) = \begin{cases} \gamma_{11} & \text{gdy } 0 \leqslant p \leqslant 1 \\ 0 & \text{gdy } 1 < p \end{cases}$$ gdy - when. Tr.

where: α_{11} and γ_{11} are certain constant values.

Analyzing the dependency (6') for the example 1, one could demonstrate that the average value of the error $\varepsilon_0(p)$ will be close to the minimal value, if we assume $\alpha_{11} = \frac{11}{32}$ and $\gamma_{11} = 1$, i.e.

$$\alpha_o(p) = \begin{cases} \frac{11}{32} & \text{gdy } 0 \leqslant p \leqslant 1 \\ 0 & \text{gdy } 1 < p \end{cases}$$ gdy - when. Tr.

$$\gamma_o(p) = \begin{cases} 1 & \text{gdy } 0 \leqslant p \leqslant 1 \\ 0 & \text{gdy } 1 < p \end{cases}$$

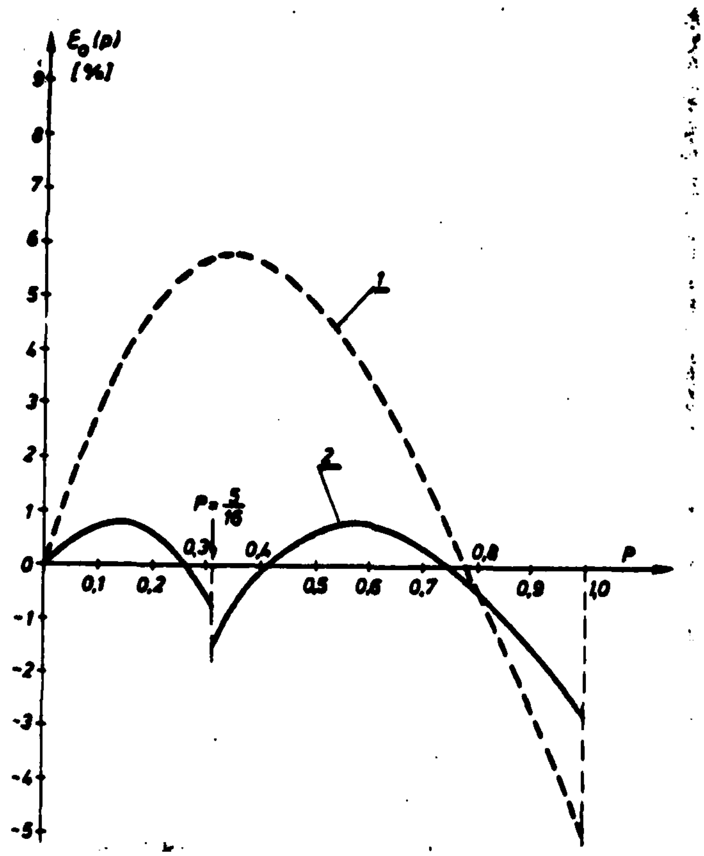

Fig. 1: A graph of the error $\varepsilon_0(p)$, (1 - for the eample 1. 2 - for the example 2.)

Example 2.

More complicated in comparison with the example 1 is the following form of the function $\alpha_0(p)$ and $\gamma_0(p)$:

$$\alpha_o(p) = \begin{cases} \alpha_{21} & \text{gdy } 0 \leqslant p \leqslant p_o \\ \alpha_{22} & \text{gdy } p_o < p \leqslant 1 \\ 0 & \text{gdy } 1 < p \end{cases}$$

$$\gamma_o(p) = \begin{cases} \gamma_{21} & \text{gdy } 0 \leqslant p \leqslant p_o \\ \gamma_{22} & \text{gdy } p_o < p \leqslant 1 \\ 0 & \text{gdy } 1 < p \end{cases}$$

From the analysis of the dependency (6') analogous to the one in the example 1, the following was obtained: $\alpha_{21} = \frac{1}{8}$, $\alpha_{22} = \frac{1}{2}$, $\gamma_{21} = 1$, $\gamma_{22} = \frac{7}{8}$ and $p_o = \frac{5}{16}$, i.e.

$$\alpha_o(p) = \begin{cases} \frac{1}{8} & \text{gdy } 0 \leqslant p \leqslant \frac{5}{16} \\ \frac{1}{2} & \text{gdy } \frac{5}{16} < p \leqslant 1 \\ 0 & \text{gdy } 1 < p \end{cases}$$

$$\gamma_o(p) = \begin{cases} 1 & \text{gdy } 0 \leqslant p \leqslant \frac{5}{16} \\ \frac{7}{8} & \text{gdy } \frac{5}{16} < p \leqslant 1 \\ 0 & \text{gdy } 1 < p \end{cases}$$

Fig. 1 presents a graph of the error $\varepsilon_0(p)$ for examples 1 and 2.

4. An Example of Realization of the System

Fig. 2 depicts a functional-bloc scheme of a system realizing the algorithm of the approximation for the example 1. Digital input signals X and Y are carried to systems M_x and M_y. On the output of those systems absolute values of signals $|X|$ and $|Y|$ are obtained. The comparator steers detectors P_1 and P_2 so that on the output of output of the P_1 detector a signal $Q=\max(|X|, |X|)$* is being received, and on the output of the P_2 detector a signal $R=\min(|X|, |Y|)$ is received. In the summer Σ_1 values of signals Q and $\frac{1}{4}\cdot R$ are summed, and in the summer Σ_2 values of $\frac{1}{16}\cdot R$ and $\frac{1}{32}\cdot R$ are summed. Values of signals $\frac{1}{4}\cdot R$, $\frac{1}{16}\cdot R$ and $\frac{1}{32}\cdot R$ are obtained as the result of moving bits by 2, 4 or 5 positions of the signal R. On the output of the summer Σ_3 the following is obtained:

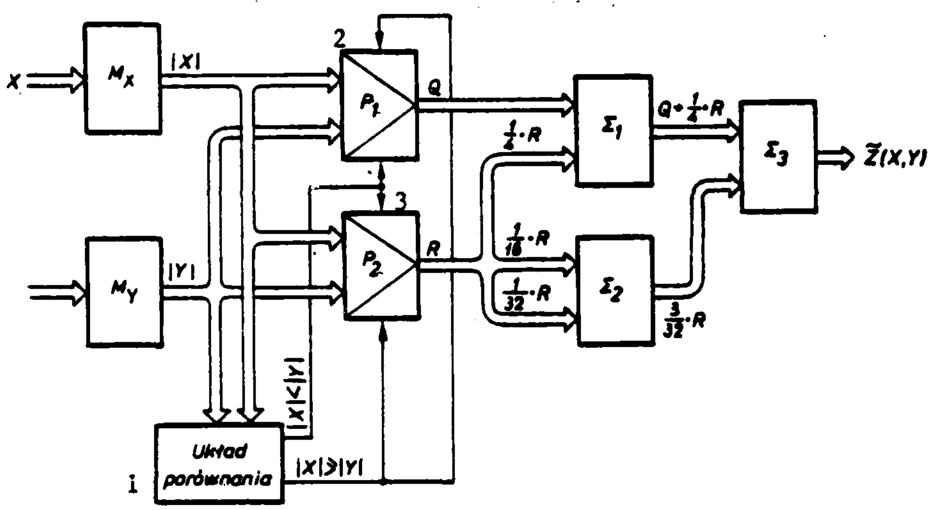

Fig. 2. A functional- bloc scheme of the system according to example 1.
1 - a comparator, 2 and 3 - detectors.

$$\tilde{Z}(X,Y)=Q+\frac{11}{32}\cdot R$$

*Most likely there is a printing error here. It should be (X , Y). Tr.

When values of input signals are X≥0 and Y≥0, systems M_x and M_y are superfluous. Such a version of the system for 8-bit input signal has been realized in a form of a standart digital packet - packet NL011A.

Fig. 3 depicts a scheme of a functional-bloc system realizing the algorithm of the approximation from the example 2.

Signals Q and R are in this system produced identically to the system form the Fig. 2. The system of the difference R_1 subtracts from the values

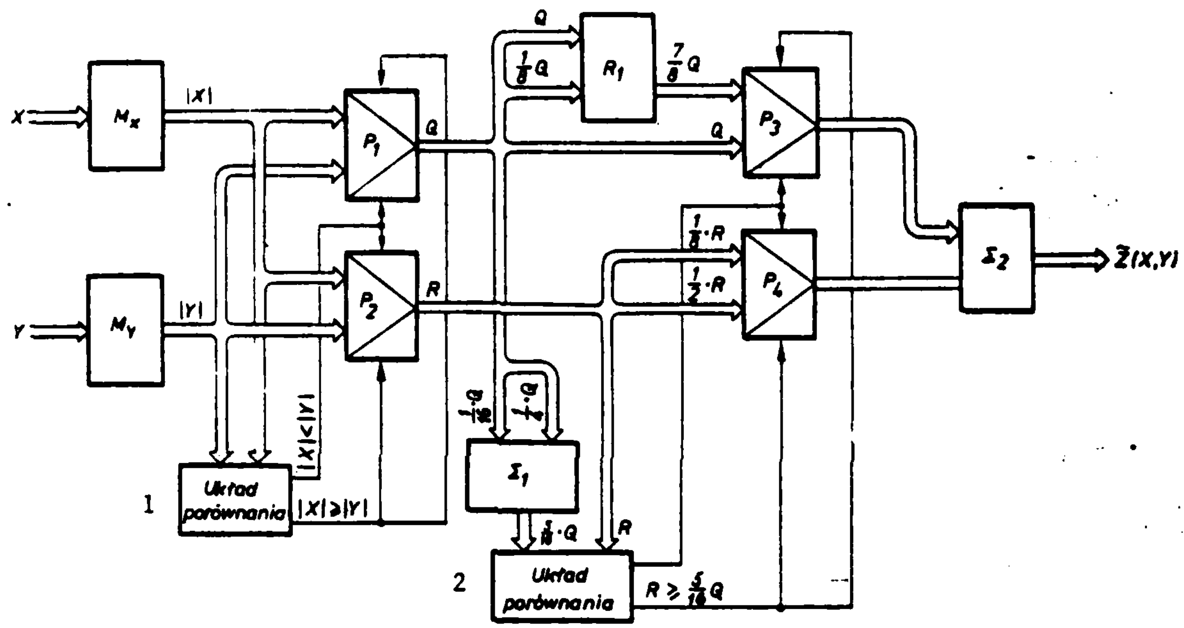

Fig. 3. The functional Bloc scheme according to the example 2.
1 and 2 - comparators

of signals Q and $\frac{1}{8}\cdot Q$, i.e. on the output of the system R_1 one obtains $\frac{7}{8}\cdot Q$. In the summer Σ_1 summing of signals $\frac{1}{4}$ Q and $\frac{1}{16}$ Q takes place. Because of this the comparator is comparing signals R and $\frac{5}{11}\cdot Q$ and steers the detectors P_3 and P_4 so that on the output of the P_3 detector signal Q is being obtained when $R< \frac{5}{16}\cdot Q$, and $\frac{7}{8}\cdot Q$ when $R>\frac{5}{16}\cdot Q$; and on the output P_4 one obtains a signal $\frac{1}{8}\cdot R$ when $R< \frac{5}{16}\cdot Q$, and $\frac{1}{2}\cdot R$ when $R \cdot \frac{5}{16}$ Q.

Because of that at the output of the summer Σ_2 one obtains:

$$\tilde{Z}(X,Y)=\begin{cases} Q+\frac{1}{8}\cdot R \text{ gdy } R<\frac{5}{16}\cdot Q \\ \frac{7}{8}\cdot Q+\frac{1}{2}\cdot R \text{ gdy } R\geqslant \cdot Q \end{cases}$$

gdy - when

This system is somewhat more developed in relation to the system form the Fig. 2., but it ensures much better accuracy of the approximation of the function $Z(X,Y)=\sqrt{X^2+Y^2}$ - see Fig. 1 (the curve 2.)

5. Final Remarks

The system for quadrature synthesising of signals we have discussed may find an application not only in digital system for processing radar signals, but also in digital systems of automatics, and in controlling-measuring digital systems.

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J. Bielski

A DIGITAL CIRCUIT FOR QUADRATURE RECEPTION OF RADAR SIGNALS

Summary

The quadrature reception of radar signals was discussed and its advantages were indicated.

The algorithm for approximate calculations of the function:

$$Z(X,Y)=\sqrt{X^2+Y^2}$$

was derived and the error of this approximation was determined. Two practical applications of the described algorithm were given and it was found that the error in the first case was less than 6% while in the second case was less than 3%.

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